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# Decision Techniques for Evaluating Fire Plans Using FOCUS Simulation

George T. Flatman  Theodore G. Storey

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Cost-plus-loss analysis and benefit/cost analysis are two techniques that fire managers can apply to FOCUS computer simulation output for alternate fire plans to help them choose the best plan. FOCUS (*F*ire *O*perational *C*haracteristics *U*sing *S*imulation) calculates costs and damages for a base plan and each alternative plan selected for testing. Cost-plus-loss and benefit/cost may then be computed which will reveal the best plan. A sensitivity analysis of the relative rankings to errors in damage estimates demonstrates that the damage estimates are reliable enough to use in the other two analyses. This note describes and illustrates how the cost-plus-loss and benefit/cost methods, in conjunction with FOCUS simulation, can help to quantify the evaluation of a variety of fire planning decisions.

*Retrieval Terms*: fire suppression strategy; benefit cost analysis; fire damage (economic); decisionmaking; computer programs; FOCUS

Until recently, the use of sophisticated decision tools—costs-plus-loss and benefit/cost—by the fire planner was restricted by the lack of objective estimates of suppression costs and damages for alternate plans. With the development of a new simulation model called FOCUS, this difficulty has been reduced.[1,2] FOCUS (*F*ire *O*perational *C*haracteristics *U*sing *S*imulation) makes it possible for the planner to estimate more objectively the costs and acres burned with alternative fire plans.

The FOCUS user is required to devise the alternative plans and choose potential damage values that will express in dollars the damage to the planned renewable resource uses and outputs of the areas burned. Then the plans are run through FOCUS which computes their respective costs and damages. The costs and damages may then be used in cost-plus-loss analysis and benefit/cost analysis, as described below to determine the best plan. Because of the present controversial nature of damage estimates, an additional analysis—a sensitivity analysis—is used to show the stability or insensitivity of the best plan to damage estimates. A sensitivity analysis of the rankings of the FOCUS output, as done here for damage estimates, would be done in a similar manner for costs, mix of fire-workload years, or any other questioned input. The FOCUS outputs and analyses of them do not give the decision. They contribute to a decision space that equips the fire manager to make his choice. A "decision space" is the presentation or bringing together of the relevant information, both monetary and nonmonetary, with the appropriate analyses.

FOCUS allows the manager to test: (1) mixes of fire suppression forces (dry crews, wet crews, bulldozers, etc.), (2) fire occurrence or spread rate modifications (closure policy, fuel modification, prevention program), and (3) road network (shorter travel times, more links). This note discusses and illustrates how the two types of analysis—cost-plus-loss and benefit/cost—can help to quantify the evaluation of a variety of fire planning decisions using the FOCUS simulation.

# Types of Analyses

The two types of analysis—cost-plus-loss and benefit/cost—require that benefits and costs be defined consistently. In cost-plus-loss analysis, as its name implies, the costs of the plan are added to the losses sustained with the plan in effect. These calculations are repeated for alternate plans and the sums are then compared. The plan with the smallest sum, i.e., minimum cost-plus-loss, is usually the best plan subject to other constraints, as we explain later. Any number of alternate plans may be included.

In benefit/cost analysis, the ratios of incremental benefit and cost are compared for all combinations of the plans involved. The best plan, subject to other constraints, is the plan that has a ratio greater than 1.0 in all comparisons. Incremental benefits are the reductions (negative) in costs and/or damages, while incremental costs are the increases (positive) in costs and/or damages compared to other plans. As with cost-plus-loss, any number of other plans may be included.

The FOCUS computer printout sheets entitled COST SUMMARY from the FOCUS cost module contain all of the data needed for applying both types of analysis to nonescape fires (fires that burn less than 100 acres (40 ha); an escape fire is one which burns 100 acres or more). FOCUS will generate separate printouts for the sample base plan and each alternative. The bottom line of each sheet contains the pertinent data, including fixed costs, suppression costs, and potential damages. Fixed costs, as used here, refer to those costs incurred by a fire plan even if no fires occurred during the fire season. Fixed costs apply to nonescape and escape fires. Costs and damages for nonescape fires for a sample base plan are shown in *table 1,* column 2. If escape fires are to be included, their costs and damages, shown in column 3, must be added to those in column 2 (*table 1*). In many cases, escapes represent a significant portion of cost and damage.

Table I—*Costs and damages by fire type with the base plan.*

| Items | Nonescape fires | Escape fires | Totals |
|---|---|---|---|
| | *Dollars* | | |
| Fixed cost | 2,197,000 | | 2,197,000 |
| Suppression costs | 345,000 | 640,000 | 985,000 |
| Potential damages | 2,708,000 | 9,180,000 | 11,888,000 |

[1]Total fixed cost applies to both nonescape and escape fires. A nonescape fire is one that burns less than 100 acres (40 ha); an escape fire is one that burns 100 acres (40 ha) or more.

Escape fires presently are "gamed" outside FOCUS simulation. Gamers are local experts who are given relevant fire information, including maps and computer printouts. They follow a precise set of rules in calculating acres burned, costs, and damages.[2]

## Cost-Plus-Loss

Let us look at an actual case made up of the status-quo base plan and three suggested alternatives A, B, and C to illustrate the calculations (*table 2*). Fixed costs, total suppression costs, and total potential damages are summed to get the cost-plus-loss total in column 5 *(table 2*). The base plan and alternatives may then be ranked in ascending order of cost-plus-loss with the plan having the lowest cost-plus-loss assigned number 1 ranking (column 6, *table 2*). Ranking is a substitute for the traditional cost-plus-loss graph.[3,4] Ranking presents the facts (discrete cost-plus-loss totals per plan) and avoids the artist's concepts and theoretician's speculations about where the minimum point on a continuous cost-plus-loss graph occurs.

But how does an agency determine which plan is "best?" Can it be done from the data in *table 2* alone? Let us start by examining the figures for the various plans and their meaning.

Plan A ranks first in least cost-plus-loss with a value of $13.1 million. However, it would probably be rejected by the agency because it requires a large increase in fixed cost—$370,000—an amount 17 percent more than the current budget. It would be difficult for a fire organization to sell its agency on so large a budget increase regardless of how great the benefit (reduction in total losses)—in this case, $2.2 million ($11.9 million − 9.7 million) or 18-½ percent.

Table 2—*Cost, damage, cost-plus-loss, and ranking of base plan and alternatives*[1]

| Plans (1) | Fixed costs (2) | Total suppression costs (3) | Total potential damages (4) | Cost plus loss (5) | Rank (6) |
|---|---|---|---|---|---|
| | *Millions of dollars* | | | | |
| A | 2.57 | 0.86 | 9.7 | 13.1 | 1 |
| B | 2.23 | .95 | 11.3 | 14.5 | 2 |
| Base | 2.20 | .98 | 11.9 | 15.1 | 3 |
| C | 2.08 | 1.04 | 12.5 | 15.6 | 4 |

[1] Includes nonescape and escape fires. A nonescape fire is one that burns less than 100 acres (40 ha); an escape fire is one that burns 100 acres (40 ha) or more.

Plan B, which ranks second lowest in cost-plus-loss at $14.5 million, appears to have a small, acceptable increase in fixed cost—$30,000—or less than 1-½ percent over the base plan budget. Losses would be reduced by $600,000, or 5 percent.

Plan C actually involves a $120,000 budget cut. But since total losses would *increase* (by $600,000), this plan might be rejected by the agency as "too risky." An agency might hesitate to approve a plan that would increase damage substantially.

What have we learned so far? It would appear that the "best" plan must have a cost-plus-loss sum that falls within a given range of fixed cost. This range is beyond the scope of FOCUS to determine, but is an essential statistic of the decision space. Only the individual agency can assess this limit considering such factors as politics, the general state of the economy, and the specific values at risk in the planning unit.

A sensitivity analysis of the ranking process can be made to show the range of an imprecise input, such as damage, over which the best plan retains its first rank. Provided with objective estimates and critical ranges of questioned inputs, the decision-maker is better equipped to make his choice.

## Sensitivity Analysis of Cost-Plus-Loss Results

Damages were selected for study because damage data and damage appraisal methods are imprecise and controversial. And in our example (*tables 1* and *2*), damages are three or four times larger than costs. The damage figures used in FOCUS and in *tables 1* and *2* are the U.S. Forest Service's 1972 Planning Damage Potential Values,[5] the *maximum* damage possible. In practice, however, these maxima are seldom reached except in the most intense forest fires. Actual damage from most fires amounts to a substantial portion of the potential damage (fire can result in "minus damages" or benefits, but these will not be considered here). A Policy Analysis Staff Report states that estimated actual damages average 10 percent of potential damages.[6] The question then becomes: How small a percentage of potential (maximum) damages can actual damages be for plan B to retain first rank (having the lowest cost-plus-loss total)? A successive pairwise comparison of plans using simple algebra and the data in *table 2* can do this for us:

Let FC = Fixed Costs
TSC = Total Suppression Costs
TPD = Total Potential Damages
AD = Actual Damage
d = AD/TPD

The range of devaluation (d) of plan B before it loses its ranking to the base plan is:

$$(FC + TSC + d \times TPD)_B < (FC + TSC + d \times TPD)_{Base}$$
$$(2.23 + 0.95 + d \times 11.3)_B < (2.20 + 0.98 + d \times 11.9)_{Base}$$
$$3.18 + 11.3d < 3.18 + 11.9d$$
$$.00 < 0.6d$$
$$.00 < d$$
$$d > 0 \text{ percent}$$

In other words, if there is any damage at all, plan B is preferable to the base plan.

And the range of d for which plan B keeps its ranking, i.e., stays "less than" plan C in cost-plus-loss, is:

$$(FC + TSC + d \times TPD)_B < (FC + TSC + d \times TPD)_C$$
$$(2.23 + 0.95 + d \times 11.3)_B < (2.08 + 1.04 + d \times 12.5)_C$$
$$3.18 + 11.3d < 3.12 + 12.5d$$
$$0.06 < 1.2d$$
$$0.05 < d$$
$$d > 5 \text{ percent}$$

Since plan A was rejected on the basis of a criterion independent of damages (namely, too large an increase in fixed cost), it is not necessary to include alternative A in the pairwise comparisons, and we select the plan with the largest value of d, which is 5 percent for plan C. This value tells us that actual damages need only amount to more than 5 percent of potential damage in order for plan B to save

money. Although many would question actual damage equal to potential damage, most would agree that, over a season or seasons, actual fire damage will exceed 5 percent of potential and that 5 percent is a conservative figure. Therefore, the choice of plan B as the best plan is a safe dollar decision.

## Benefit/Cost

The same basic data used in cost-plus-loss can be used in benefit/cost analysis (*table 3*). Each plan must be compared to all other plans. And a plan may be eliminated when it has a benefit/cost ratio less than 1.0. All pairwise combinations must be included. In our example, it is logical to start with the base plan as status quo or reference and subtract its values from those for each alternative (top half of *table 3* labeled, "Comparisons to base plan"). Using fixed cost (column 2) as an example, we subtract 2.20 from it and from each of the other values in column 2. We record the differences in column 3. This is repeated for total suppression costs (column 4) and total damages (column 6) and the differences recorded in columns 5 and 7, respectively. The differences are called incremental or delta ($\Delta$) differences and they may be either positive or negative in sign.

Now, "benefit" and "cost" must be defined. These terms are not obvious in the context of natural resource management.[7] This is because both costs and damages are monies out of the taxpayer's pocket, a positive increment of either one is a cost, but a negative increment of any one is a benefit. Another way of stating it is, the total benefit (B) is the sum of the absolute values of all negative increments, total cost (C) the sum of all positive increments.

Mathematically:

$$B = \Sigma|\Delta X_i| \text{ over all } \Delta X_i < 0$$

$$C = \Sigma|\Delta X_i| \text{ over all } \Delta X_i > 0$$

If we accept these definitions of B (benefit) and C (cost), the question of whether negative cost is a cost or a benefit, or negative benefit is a benefit or a cost, is resolved. The benefit/cost ratio (column 10), is the quotient of the total benefit, column 8, divided by the total cost, column 9 (*table 3*).

The first set of comparisons to the base plan (top half of *table 3*), tells us (1) plan A is acceptable and eliminates the base plan, (2) plan B is acceptable and also eliminates the base plan, and (3) plan C is eliminated by the base plan; but the base plan was eliminated in (1) and (2), leaving us with only plans A and B as viable candidates for best plan. These two surviving plans must now be compared.

Choosing plan B as reference we subtract its values from those for plan A and compute the benefit/cost ratio (lower half, *table 3*). The fact that the benefit/cost ratio is greater than 1.0 tells us that plan A is the better plan.

Table 3—*Incremental costs and damages, benefits, costs, and benefit/cost ratios for base plan and alternatives*

| Plan (1) | Fixed costs (2) | Incremental fixed costs (3) | Total suppression costs (4) | Incremental suppression costs (5) | Total damages (6) | Incremental damages (7) | Benefits ($\Sigma\|-\Delta$ costs and damages$\|$) (8) | Costs ($\Sigma+\Delta$ costs and damages) (9) | Benefit /cost ratios (10) |
|---|---|---|---|---|---|---|---|---|---|
| | *Millions of dollars* | | | | | | | | |
| | **Comparisons to base plan** | | | | | | | | |
| A | 2.57 | 0.37 | 0.86 | −.12 | 9.7 | −2.2 | 2.32 | 0.37 | 6.3 |
| B | 2.23 | .03 | .95 | −.03 | 11.3 | −.6 | .63 | .03 | 21 |
| Base | 2.20 | 0 | .98 | 0 | 11.9 | 0 | 0 | 0 | — |
| C | 2.08 | −.12 | 1.04 | .06 | 12.5 | .6 | .12 | .66 | .2 |
| | **Comparisons to plan B** | | | | | | | | |
| A | 2.57 | .34 | .86 | −.09 | 9.7 | −1.6 | 1.69 | .34 | 5.0 |
| B | 2.23 | 0 | .95 | 0 | 11.3 | 0 | 0 | 0 | — |

Examination of our analysis up to now reveals that we have created for the manager a "decision space." We believe that this decision space will help him make the best decision. In our example, plan A was rejected because it required too much increase in fixed costs even though it was first choice of both cost-plus-loss and benefit/cost ratio.

## Sensitivity Analysis of Benefit/Cost Results

A test of the sensitivity of the ranking of the benefit/cost ratios is recommended for the surviving plans B and C in the benefit/cost findings. It is needed to clear up uncertainty as to the percentage (d) that actual damages are to potential damages, mentioned earlier.

The benefit/cost ratio for plan B is compared pairwise to the base plan and alternative C to determine if they equal or exceed the minimum "attractive" ratio. Let us assume the ratio is greater than 1. First we compare plan B with base plan. The *incremental* values for plan B minus base plan are given in line 2, columns 5 and 7 (*table 3*):

$$\begin{aligned}(\text{B/C of plan B—base plan}) &> 1.0\\ (.03 + .60d)/.03 &> 1.0\\ 1 + 20d &> 1.0\\ d &> 0 \text{ percent}\end{aligned}$$

This result tells us that plan B is a profitable choice over the base plan as long as real damages are positive. Now, we will consider plan B as opposed to plan C.

The incremental values for plan B minus plan C are not given in *table 3* but can be obtained from the given values by subtraction, lines 2 and 4 (*table 3*):

$$\begin{aligned}(\text{B/C of plan B—plan C}) &> 1.0\\ (.09 + 1.2d)/.15 &> 1.0\\ d &> 5 \text{ percent}\end{aligned}$$

This result indicates that plan B is a profitable choice over plan C so long as real damages are equal to or greater than 5 percent of potential damages.

Further, the results tell us that in both cost-plus-loss and benefit/cost ratio, the optimum solution is stable with regard to damage, or damage seems to be insensitive.

## Comparison of the Two Techniques

To examine mathematically how the two types of analysis differ:
Cost-plus-loss defines:

$F$ = \$ of Fixed Cost to be the abscissa, if plotted
$S$ = \$ of Suppression Cost
$D$ = \$ of Damage
$S + D$ is the ordinate

Benefit/cost defines:

$C = \Delta F$ (assuming increasing costs, so $\Delta F > 0$)
$B = |\Delta(S + D)|$ and $\Delta S < 0, \Delta D < 0$
or $-B = \Delta(S + D)$

The stopping rule for cost-plus-loss is to locate the relative minimum for the sum of F, S, and D. This can be written:

$\frac{d}{dF}(F + S + D) = 0$, if $F + S + D$ were continuous and differentiable

$1.0 + \frac{d(S + D)}{dF} = 0$, if $\lim \frac{\Delta(S + D)}{\Delta F} = \frac{d(S + D)}{dF}$

$1.0 + \frac{\Delta(S + D)}{\Delta F} = 0$

$1.0 + (\frac{-B}{C}) = 0$

$\frac{B}{C} = 1.0$

If we assume decreasing costs in the benefit/cost ratio:

$B = \Delta F$ if $\Delta F < 0$
or $-B = \Delta F$

$C = \Delta(S + D)$ and $\Delta S > 0, \Delta D > 0$

Then:

$\frac{d}{dF}(F + S + D) = 0$, assume $Y = F + S + D$ is continuous and differentiable

$1.0 + \frac{d(S + D)}{dF} = 0$

$1.0 + \frac{\Delta(S + D)}{\Delta F} = 0$

$1.0 + (\frac{C}{-B}) = 0$

$\frac{C}{B} = 1.0$

$\frac{B}{C} = 1.0$

And the stopping rule for benefit/cost is:

$\frac{B}{C} > 1.00$

The solution B/C = 1.0 says mathematically that cost-plus-loss goes after the last savable penny; in contrast, benefit/cost ratio goes after every penny on which it is possible to make a profit in saving (B/C>1.0).

# Conclusions

Cost-plus-loss analysis and benefit/cost analysis are two techniques by which fire managers can evaluate alternate fire plans, using FOCUS simulation output, to help them choose the best plan. Each technique has its merits and both should be considered in deciding which fire plan to implement. The plan with minimum cost-plus-loss or a benefit/cost ratio greater than 1.0 in all pairwise comparisons is the most efficient of the plans being considered, but may not be practical in light of political or other considerations. For example, it might reduce losses dramatically, but in a recessive economy, might be too costly to implement. Considerations of this type are beyond the scope of this study. Both techniques are limited to the plans included in the test. There is no way of knowing if a more profitable plan may have been left out.

The fact that the damage values presently in use are imprecise and represent maximum potential damage—rather than actual damage—limits, to some extent, use of either type of analysis. It is demonstrated mathematically, however, that sensitivity analysis of the rankings minimizes this problem by finding the critical limit for a questionable factor. In our example for both types of analysis, the most profitable plan will not change unless actual damages are less than 5 percent of potential damages. This seldom occurs in practice—nearly all fires will cause damage amounting to more than 5 percent of the maximum possible. This is not to minimize the importance of better damage values. These are urgently needed and will improve the scope and reliability of the FOCUS evaluations.

## NOTES

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**The Authors**

are assigned to the Station's fire management planning and economics research unit, with headquarters at the Forest Fire Laboratory, Riverside, Calif. **GEORGE T. FLATMAN**, a mathematician, earned degrees in mathematics at the University of Cincinnati (B.A., 1953) and in theology at Fuller Theological Seminary (B.D., 1956). He joined the Forest Service and Station staff in 1967. **THEODORE G. STOREY**, a research forester, is a forestry graduate of the University of California, Berkeley (B.S., 1948; M.S. 1968). He has served continuously on the Station staff since 1949, except for the period 1955-1962, when he was assigned to the Southeastern Forest Experiment Station, at Asheville, N.C.